Joint Concept of Operations
for Cooperative Lunar Relay and Navigation Services

Basic Functional Description

**A Collaboration between the European Space Agency (ESA)
and the National Aeronautics and Space Administration (NASA)**

December 15, 2022

Joint Concept of Operations for Cooperative Lunar Relay and Navigation Services

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Joint Concept of Operations for Cooperative Lunar Relay and Navigation Services

1. Purpose

This description of a Joint Concept of Operations for Lunar Relay and Navigation Services is a collaboration between ESA and NASA that is intended, in the 2022 timeframe, to provide a basic functional description of how the two agencies would manage the interface between their respective lunar communications and navigation services to support NASA and ESA missions using initially available capabilities in an efficient and complementary manner. The concept of operations will be defined in greater detail in the future and its evolution will take into consideration the inputs of commercial vendors that will be engaged to provide services as well as input from users.

The concept of operations description can provide background and context for more formal partnership agreements between NASA and ESA. The concept will also provide a starting point for detailed technical planning and implementation in the future and serve as a template for incorporating additional new partners in cooperative lunar communications and navigation operations.

2. Scope of the Operations Addressed

ESA and NASA plan to procure lunar relay and navigation services to be deployed and operated by commercial vendors. Relay service vendors are to provide the complete communications path between the user's systems at the Moon and transmitting and receiving stations on the Earth. These vendors are also expected to provide point-to-point and broadcast navigation services to users at the Moon. (Navigation services are also referred to here as position, navigation and timing (PNT) services.)

The concept of operations, at this time, is limited to lunar communications relay and PNT services at the Moon, including NASA's planned procurement of relay services and ESA's Moonlight program. The concept is intended to accommodate additional service capabilities, as they are introduced. The concept is also intended to accommodate the future incorporation of other partners beyond NASA and ESA. Other service providers including the ESA Lunar Pathfinder, the Gateway relay capability, and direct-to-Earth services could be added to the cooperative lunar network in the future but are not addressed here.

The joint concept of operations described in this document addresses the following:
- A common set of definitions and terminology to describe the operations taking place and the interactions involved in the exchange of lunar relay and PNT services
- The process and logical steps to be executed separately and/or jointly in order to enable the exchange of services
- The roles and responsibilities associated with the process
- A high-level definition of the operational interfaces required to implement the cooperative exchange of services.

Note: More detailed technical details will be defined at a later time.

3. Role of the Interagency Steering Board

This joint concept of operations envisions the creation of an Interagency Steering Board that will:
- Guide the establishment and evolution of cooperative lunar communications and navigation network services mutually provided by NASA and ESA
- Provide strategic guidance for network operations based on the agreements between the agencies and reflecting the contractual or other arrangements each agency has made with their respective service providers and users
- Oversee implementation of interoperability standards and procedures
- Seek agreements on orbital locations for lunar orbit assets for mutual benefit to the greatest extent possible
- Establish policies, practices, and ground rules for service allocations, prioritization, and optimization
- Account for financial compensation or barter arrangements for cooperative services

The Interagency Steering Board may be expanded in the future to include other international partners that contribute service capabilities to the cooperative lunar network.

4.1 Validation of Service Providers

Each agency has the responsibility to conduct its own validation of their sponsored service providers. With respect to providers that will be serving mission users from both agencies, there will be a validation process, to be defined in the future, to ensure confidence in the cooperative operations. This validation process will be applied to any new service providers that are brought into the cooperative network by either partner agency.

NASA and ESA will require their respective service providers to comply with the Lunanet Interoperability Specification.

Cross-support validation, as well as validation in general, is an area of potential collaboration between NASA and ESA. The process of validating assets, especially those deployed at the Moon, might take advantage of earlier lunar missions or payloads hosted on those missions as test-case users or calibration sources.

4.2 Service Monitoring

Each agency has the responsibility to establish requirements for its own service providers to monitor their lunar relay and PNT services while operational in orbit. Service monitoring may require the deployment of in-situ assets which may impose additional costs. Cooperative support for service monitoring is another area of potential collaboration between NASA and ESA.

5. Functional Steps in Operations

1. Authorization
2. User Onboarding
3. Planning
4. Scheduling – Pre-execution, Dynamic, and Emergency
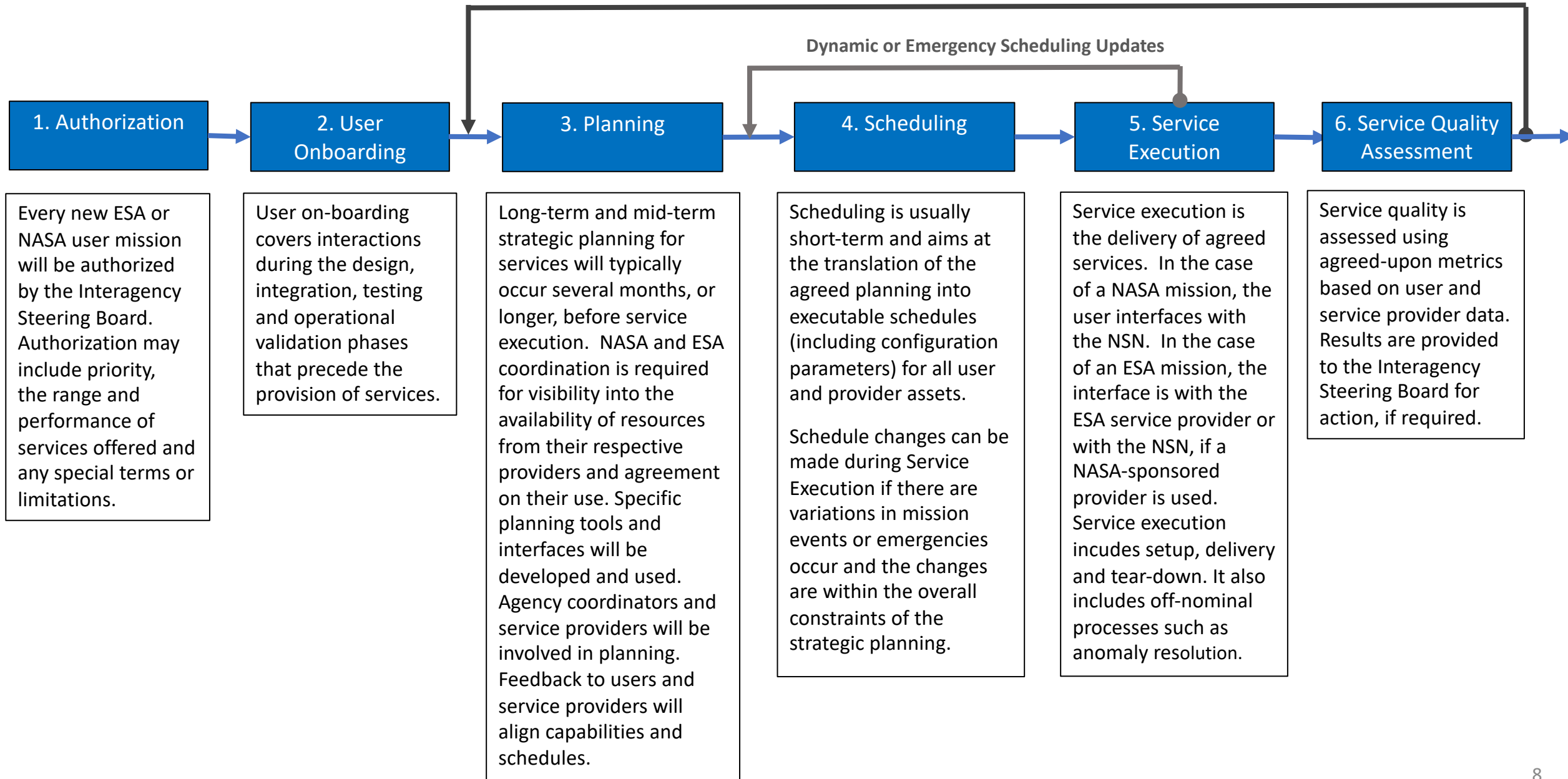5. Service Execution
6. Service Quality Assessment

Diagrams with explanatory text for each of these steps follows.

An important note for these functional steps is that NASA intends to maintain a centralized, government interface between its users and its sponsored service providers through all operational steps. The NASA interface is referred to as the Near Space Network (NSN).

ESA will have an agency coordination function for some of the steps, but for the most part, will delegate the interface role with its users to their sponsored service provider. The ESA sponsored service provider, will in many cases, interface with the NSN.

5. Functional Steps in Operations

Recurrent planning, scheduling and service provision for authorized users

Dynamic or Emergency Scheduling Updates

1. Authorization	2. User Onboarding	3. Planning	4. Scheduling	5. Service Execution	6. Service Quality Assessment

Every new ESA or NASA user mission will be authorized by the Interagency Steering Board. Authorization may include priority, the range and performance of services offered and any special terms or limitations.

User on-boarding covers interactions during the design, integration, testing and operational validation phases that precede the provision of services.

Long-term and mid-term strategic planning for services will typically occur several months, or longer, before service execution. NASA and ESA coordination is required for visibility into the availability of resources from their respective providers and agreement on their use. Specific planning tools and interfaces will be developed and used. Agency coordinators and service providers will be involved in planning. Feedback to users and service providers will align capabilities and schedules.

Scheduling is usually short-term and aims at the translation of the agreed planning into executable schedules (including configuration parameters) for all user and provider assets.

Schedule changes can be made during Service Execution if there are variations in mission events or emergencies occur and the changes are within the overall constraints of the strategic planning.

Service execution is the delivery of agreed services. In the case of a NASA mission, the user interfaces with the NSN. In the case of an ESA mission, the interface is with the ESA service provider or with the NSN, if a NASA-sponsored provider is used. Service execution incudes setup, delivery and tear-down. It also includes off-nominal processes such as anomaly resolution.

Service quality is assessed using agreed-upon metrics based on user and service provider data. Results are provided to the Interagency Steering Board for action, if required.

5. Additional Clarification of Planning, Scheduling, and Service Execution

In addition to the description provided on the previous page, some explanation is provided here to reduce ambiguity between Planning, Scheduling, and Service Execution. This definition is subject to further discussions between ESA and NASA operations teams and will also take into consideration the operations concepts of commercial vendors.
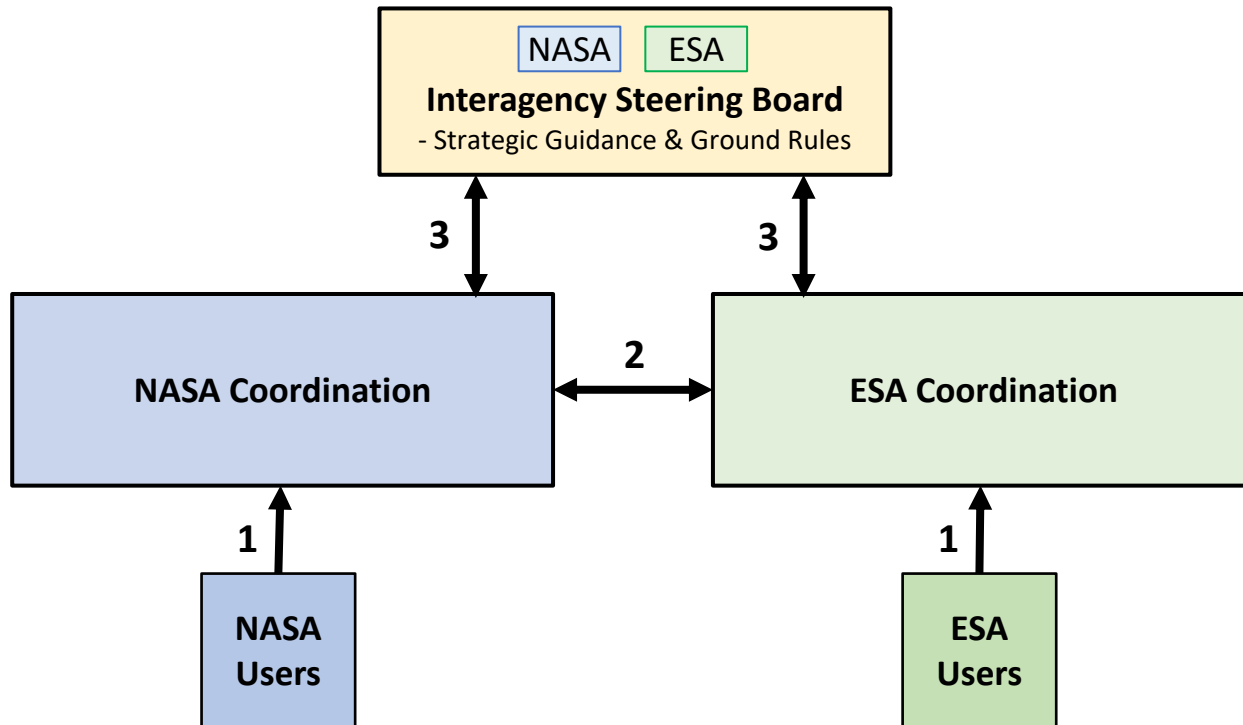
Planning is foreseen as an iterative process rather than one single step. The length of the planning cycle may vary from one service to another and the number of iterations to converge into a stable, agreed upon plan may differ depending on the service of interest and the specific user. The Planning function referred to in this joint concept of operations aims at establishing an agreed upon plan with the required level of granularity that allows the translation of these plans into executable schedules.

Scheduling can be easily confused with Planning as the two terms may be used interchangeably for valid reasons. For the purpose of this joint concept of operations, Scheduling assumes an agreed upon, stable plan than can be processed by the user and the service provider systems. These systems likely expect to distribute executable schedules a few weeks or days in advance, depending on the operations concept of each system. For example, spacecraft schedules are uploaded on-board and typically cover a week or two depending on the operational requirements. Scheduling involves the definition of executable schedules for ground assets and for the user lunar assets on and around the Moon.

Changes may happen at various points during the Planning and Scheduling steps and depending on the nature of the required changes, re-planning and/or re-scheduling may be required. These details are important and can be addressed in more detail only at later stages.

Service Execution involves the distribution of the executable schedules to the lunar assets and the provision of services at the established dates and times.

1. Authorization

NASA **ESA**

Interagency Steering Board
- Strategic Guidance & Ground Rules

3   **3**

2

NASA Coordination   **ESA Coordination**

**1**   **1**

NASA Users   **ESA Users**

Every new ESA or NASA user mission will be authorized by the Interagency Steering Board. Authorization may include priority, the range and performance of services offered and any special terms or limitations.

1. A NASA User or an ESA User makes a request to its respective coordination office for acquiring services from one or more sponsored service providers. The request contains details on the required services, performance, dates, etc. The Agency agrees (or not) to authorize a given user to acquire services from a sponsored provider, based on each agency's agreements with their respective sponsored providers.

2. The two agencies exchange information on any user with a potential to use the services provided by the other agency. If cross support appears appropriate and practical, then the proposed cross support agreement is submitted to the Interagency Steering Board for authorization.

3. The Interagency Steering Board considers the request, and if appropriate, provides an authorization with a definition of the types of services to be provided, the priority, and any constraints or limitations to be applied.

A mission for which there are significant changes in the nature of the service requirements may require re-authorization.

2. User Onboarding
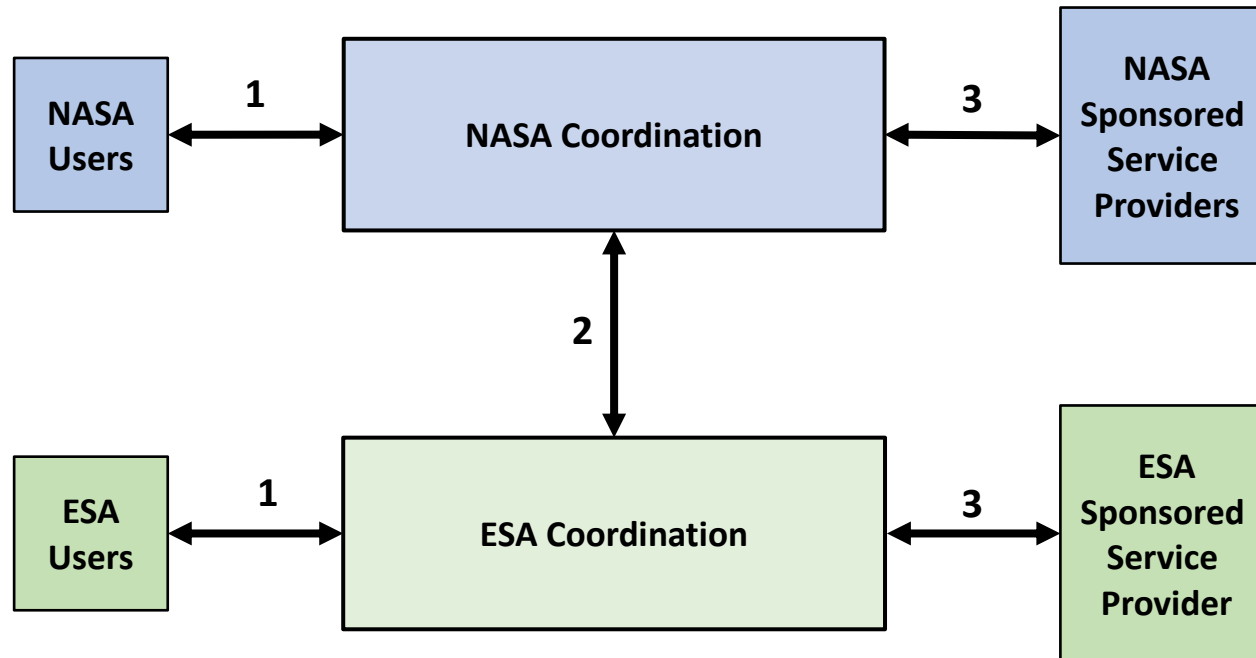
User On-Boarding covers interactions during the design, integration, testing and operational validation phases that precede the provision of services.

1. Users exchange design and performance information with the respective coordination office to determine user needs and negotiate satisfactory service provisions.

2. NASA and ESA exchange information as required for users that may utilize service providers sponsored by the other agency.

3. Coordination offices exchange information with their respective service providers to ensure adequate performance and availability of services and to determine whether any modifications are needed to meet user needs.

3. Planning
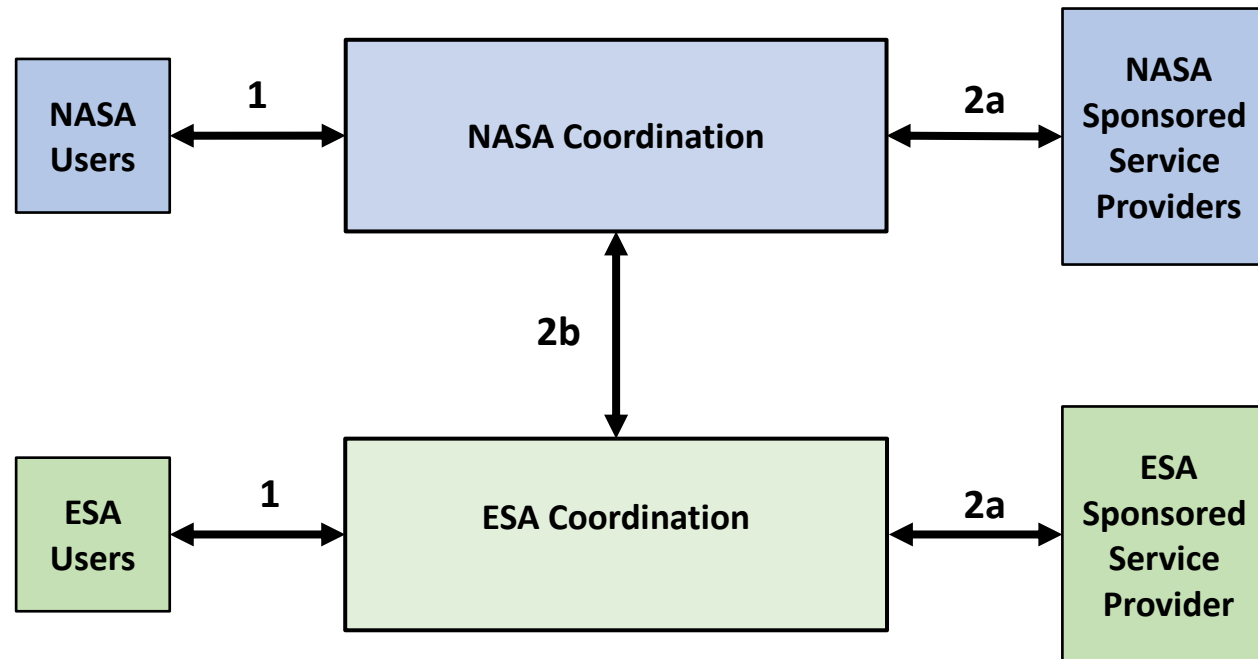
Long-term strategic planning for services will typically occur several months, or longer, before operations. NASA and ESA coordination is required for visibility into the availability of resources from their respective providers and agreement on their use. Specific planning tools and interfaces will be developed and used. Agency coordinators and service providers will be involved in planning.

1. NASA and ESA users send their long-term planning information to their respective Agency coordination office. The coordination office assesses the plan and provides feedback and/or confirmation after iterating with their respective service providers.

2a. Each Agency coordination office will have visibility into the available service capabilities and an established interface with their respective services providers to conclude the planning process.

2b. In case of services required from a partner agency, NASA and ESA coordination offices exchange planning information in order to agree on a long-term plan.

This view focuses on pre-planned type service and the picture may change for user-initiated services.

4. Scheduling
NASA User

NSN = Near Space Network (NASA)
MOC = Mission Operations Center
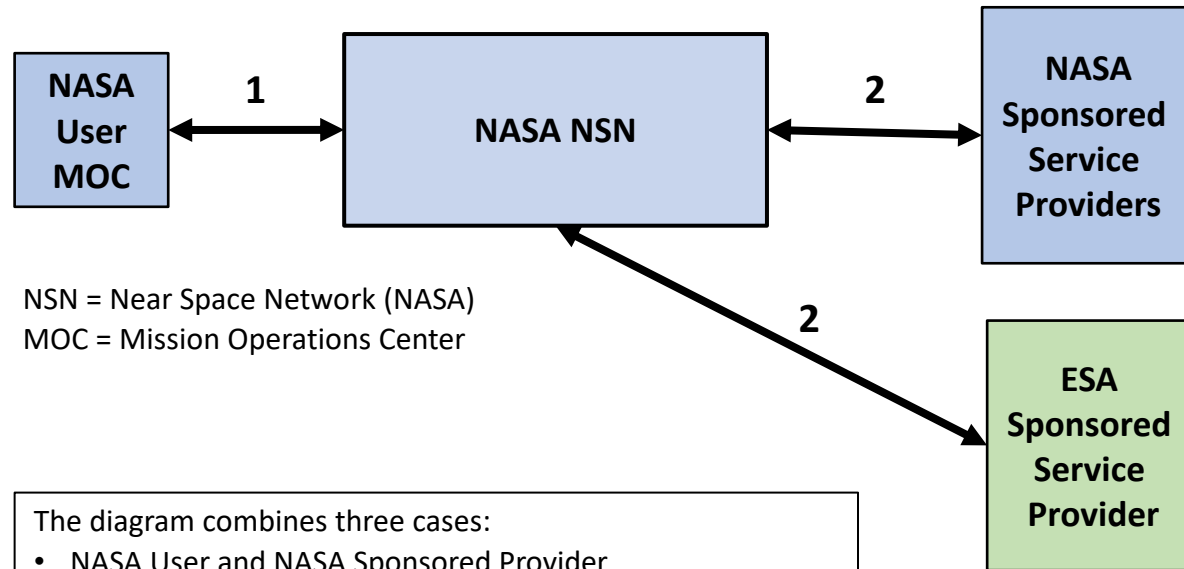
The diagram combines three cases:
- NASA User and NASA Sponsored Provider
- NASA User and ESA Sponsored Provider
- NASA User and NASA and ESA Sponsored Providers

Scheduling is usually short-term and aims at the translation of the agreed upon planning into executable schedules (including configuration parameters) for all user and provider assets.
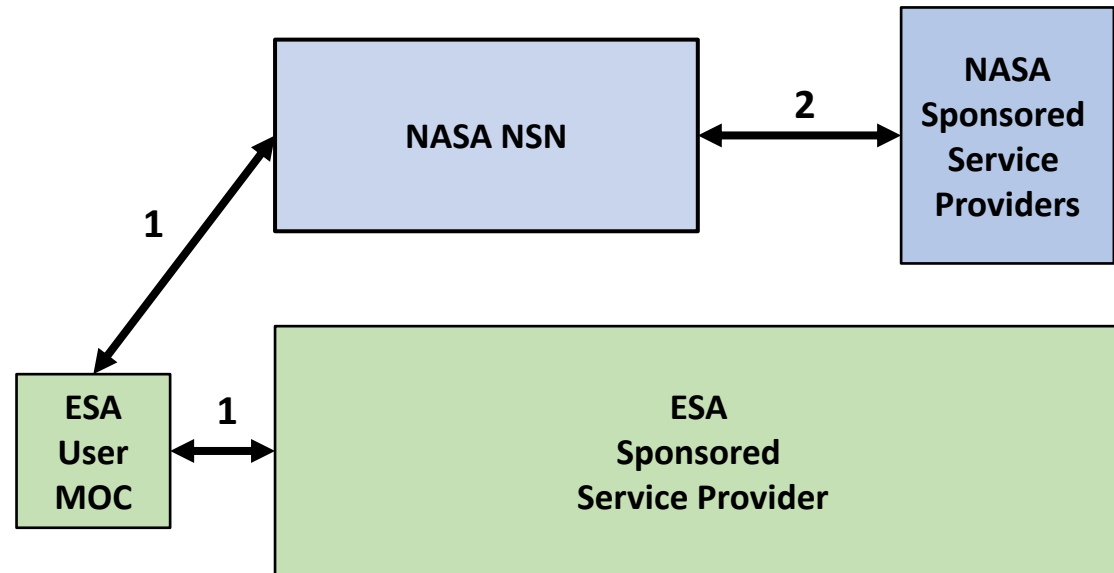
Schedule changes can be made during Service Execution if there are variations in mission events or emergencies occur and the changes are within the overall constraints of the strategic planning.

In the case of a NASA user, the user interfaces are with the NSN. The NSN will interface with a NASA service provider or with the ESA service provider.

1. NASA user and NSN determine the short-term schedule including the detailed configuration.

2. NASA NSN coordinates with ESA and/or NASA service provider on the short-term schedule including the detailed configuration

Service schedules are transferred to the user lunar segments as part of service execution.

4. Scheduling
ESA User

NASA NSN

2

NASA Sponsored Service Providers

1

ESA User MOC

1

ESA Sponsored Service Provider

The diagram combines three cases:
- ESA User and ESA Sponsored Provider
- ESA User and NASA Sponsored Provider
- ESA User and NASA and ESA Sponsored Providers

Scheduling is usually short-term and aims at the translation of the agreed upon planning into executable schedules (including configuration parameters) for all user and provider assets.

Schedule changes can be made during Service Execution if there are variations in mission events or emergencies occur and the changes are within the overall constraints of the strategic planning.

1. ESA user and the ESA Service provider and/or NASA NSN determine the short-term schedule including the detailed configuration

2. NASA NSN coordinates with NASA service provider the short-term schedule including the detailed configuration.
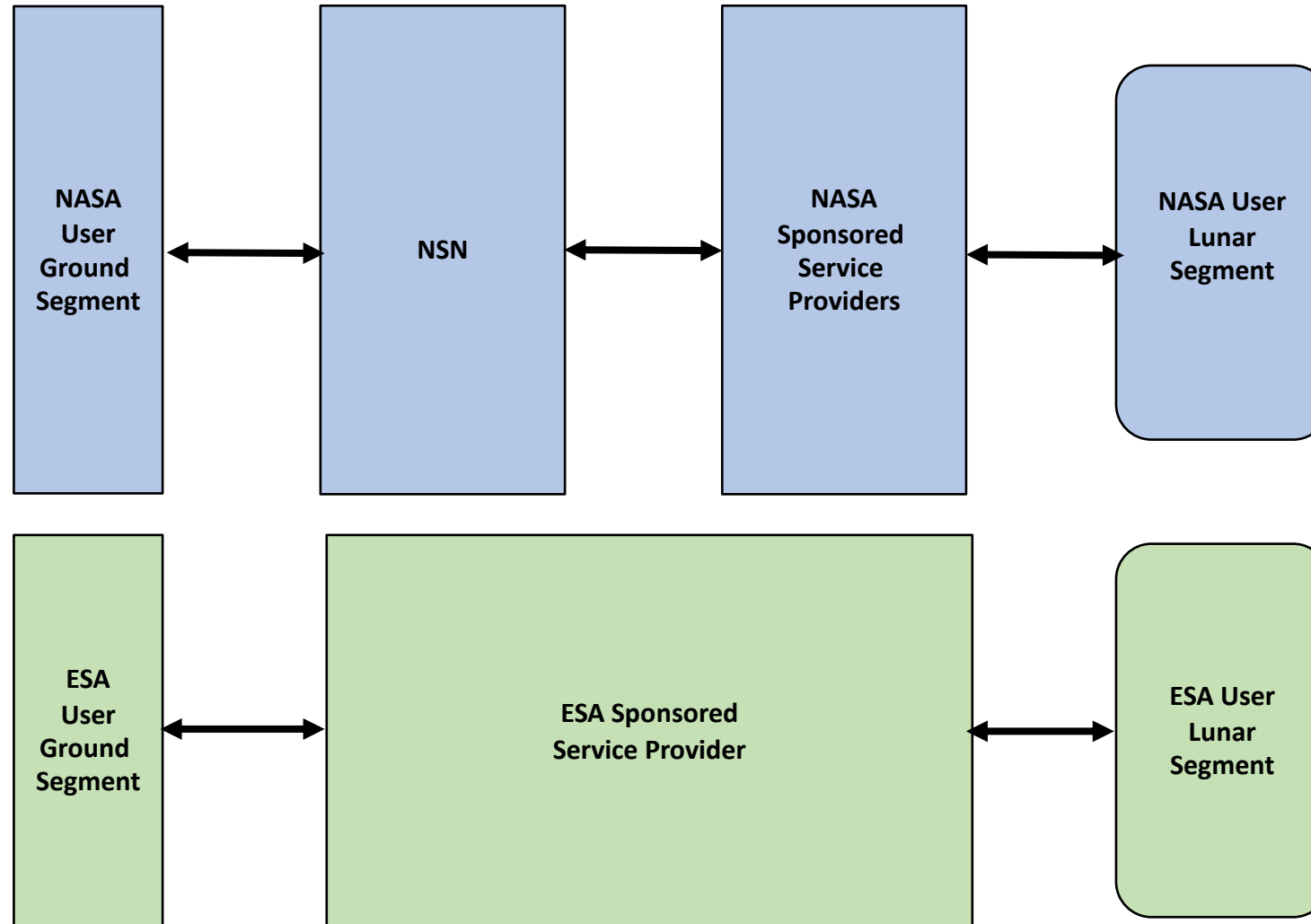
Service schedules are transferred to the user lunar segments as part of service execution.

5. Service Execution   Overview
NASA User – NASA Provider
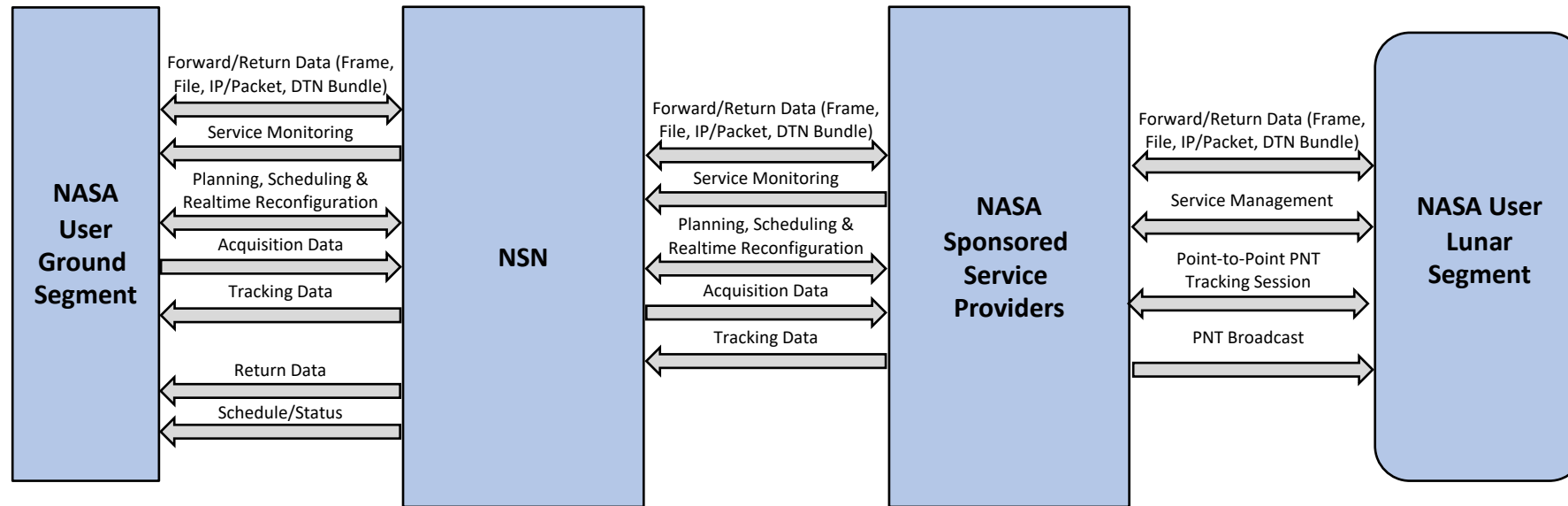### ESA User – ESA Provider

Process Flow Diagram

Service execution is the delivery of agreed services. In the case of a NASA mission, the user interfaces with the NSN. In the case of an ESA mission, the interface is with the ESA service provider or with the NSN, if a NASA-sponsored provider is used.

| NASA User Ground Segment | ⬌ | NSN | ⬌ | NASA Sponsored Service Providers | ⬌ | NASA User Lunar Segment |

| ESA User Ground Segment | ⬌ | ESA Sponsored Service Provider | ⬌ | ESA User Lunar Segment |

NSN = Near Space Network (NASA)
MOC = Mission Operations Center

5. Service Execution
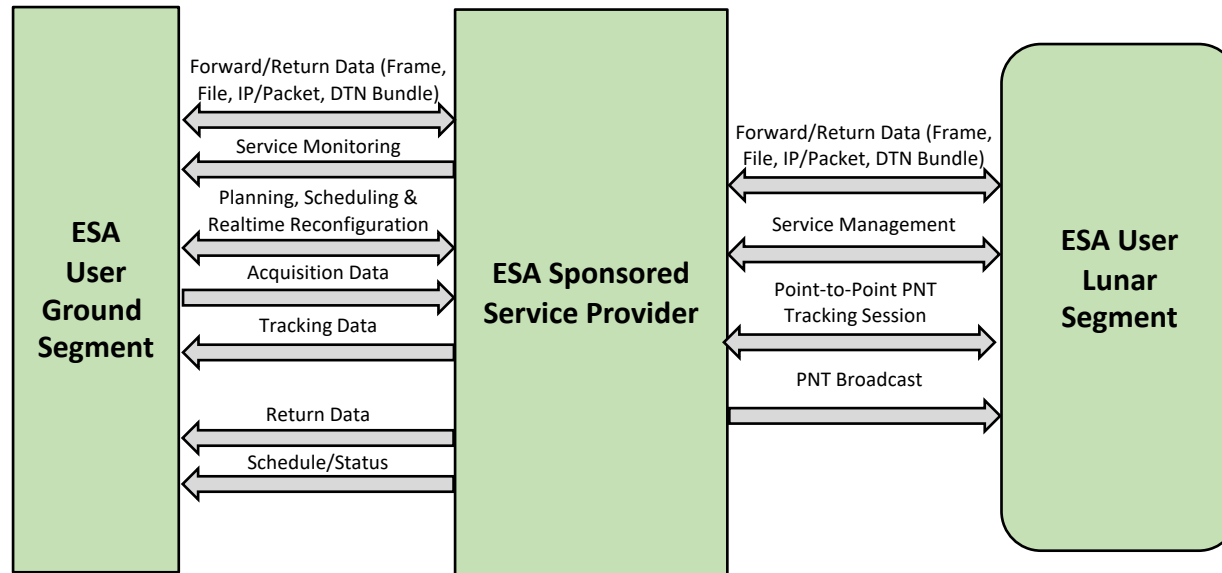
NASA User – NASA Provider

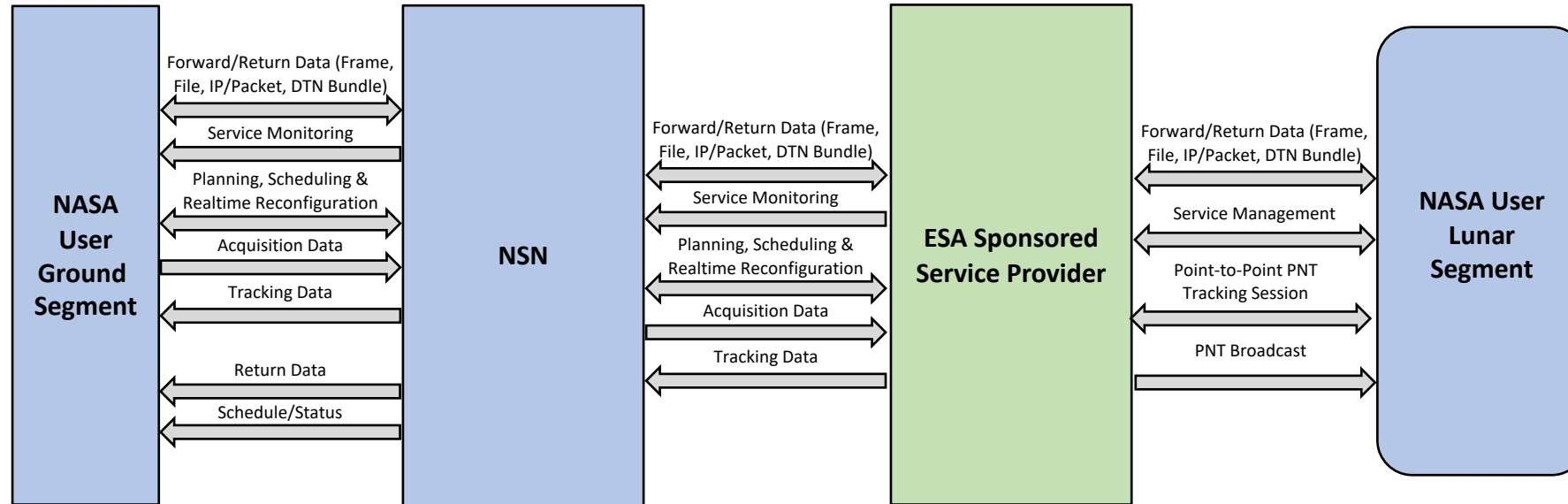**Data Flow Diagram**

5. Service Execution

ESA User – ESA Provider

Data Flow Diagram

5. Service Execution
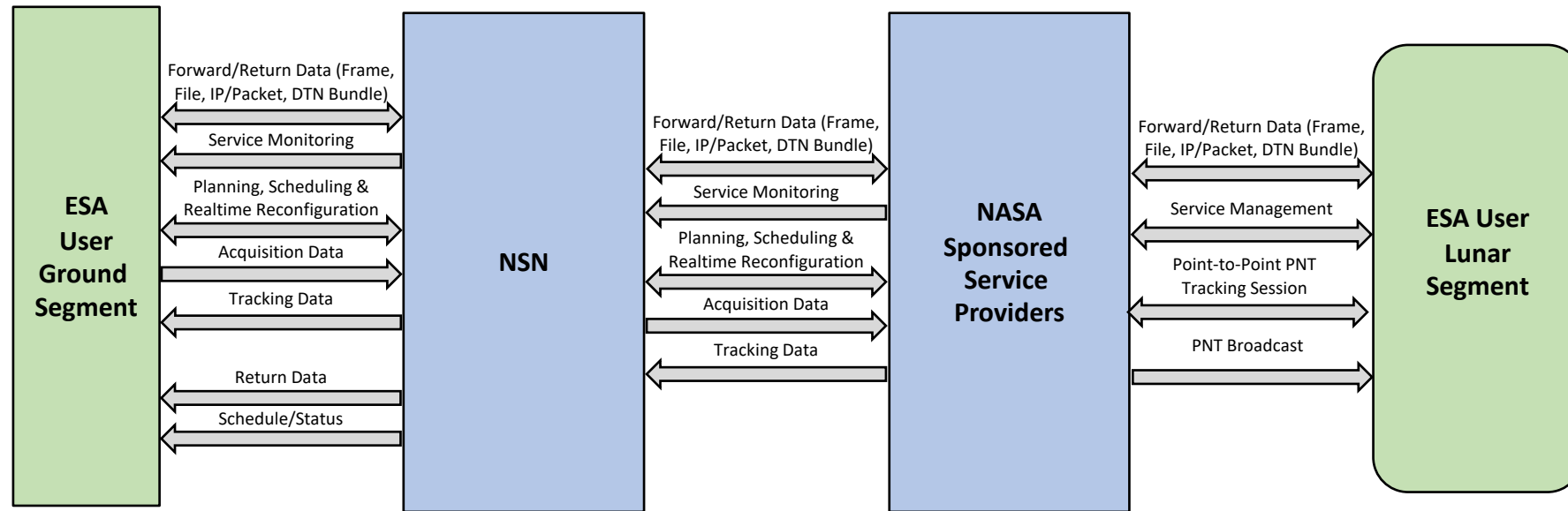
NASA User – ESA Provider

Data Flow Diagram

5. Service Execution

ESA User – NASA Provider

Data Flow Diagram

5. Areas for Future Definition and Collaboration

1. Defining additional detail on interfaces, data to be exchanged, operational processes, and other refinements for all steps of the joint concept of operations.
2. Incorporation of input from commercial service providers and the users.
3. Planning implementation of concept of operations for NASA and ESA service providers and users for lunar communications relay and navigation services.
4. Planning for potential NASA and ESA cooperation on service validation and other joint activities.
5. Consideration of expanding concept of operations to include Gateway relay service and to include direct-to-Earth communications services.
6. Potential incorporation of additional contributing partners into the cooperative lunar network.

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